

HERBICIDAL WEED CONTROL IN WINTER WHEAT (*Triticum aestivum* L.)

Mariyan YANEV

Agricultural University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: marlanski@abv.bg

Abstract

During 2019-2020 and 2020-2021 on the experimental field of the Agricultural University of Plovdiv, Bulgaria, a field experiment with winter wheat variety 'Enola' was performed. The trial included the following herbicidal treatments: *Quelex + Trend 90* (37.5 g ha⁻¹ + 0.1%); *Quelex + Trend 90* (50 g ha⁻¹ + 0.1%); *Quelex + Aminopielik 600 SL* (37.5 g ha⁻¹ + 0.4 l ha⁻¹); *Quelex + Aminopielik 600 SL* (50 g ha⁻¹ + 0.4 l ha⁻¹); *Quelex + Mustang 306,25 SC* (37.5 g ha⁻¹ + 0.3 l ha⁻¹); *Derby super one + Trend 90* (33 g ha⁻¹ + 0.1%); *Mustang 306,25 SC* (0.6 l ha⁻¹); *Sekator OD* (1.25 l ha⁻¹); *Sekator OD* (1.50 l ha⁻¹) and *Biathlon 4D + Dash* (55 g ha⁻¹ + 0.5 l ha⁻¹). The herbicides were applied in phenophase tillering of the winter wheat (BBCH 21-29). The application of *Quelex + Mustang 306,25 SC* (37.5 g ha⁻¹ + 0.3 l ha⁻¹) and *Quelex + Aminopielik 600 SL* (50 g ha⁻¹ + 0.4 l ha⁻¹) ensured excellent efficacy against *Anthemis arvensis* L., *Papaver rhoeas* L., *Consolida orientalis* J.Gay, *Vicia hirsuta* L., *Galium aparine* L., *Sinapis arvensis* L., *Lamium purpureum* L., and *Fumaria officinalis* L.. The wheat biological yield as well as the supplementary biometrical indicators for the concrete two treatments was the highest.

Key words: winter wheat, herbicides, weeds, efficacy, biometry.

INTRODUCTION

Providing plenty of food to eat the population of the Earth is an inalienable concern for humanity. All branches of biological science work intensively and purposefully to solve a large number of problems and tasks (Georgiev et al., 2019; Nenova, 2019; Nenova et al., 2019; Petrova et al., 2019; Nenova, 2017; Shopova & Cholakov, 2015; Shopova & Cholakov, 2014). The winter wheat (*Triticum aestivum* L.) is the main grain crop in Bulgaria. The weeds are the main competitors of winter wheat for water, nutrients, and light. The weeds also cause indirect damage, as many of the species are hosts of diseases and pests (Kalinova et al., 2012). The high weeds infestation can decrease the yields by up to 70% (Atanasova & Zarkov, 2005; Bekelle, 2004).

In addition to weeds, the lack of nutrients, which is often caused by them, also harms the formation of crop yields (Ivanov et al., 2019; Manolov & Neshev, 2017; Neshev & Manolov, 2016; Kostadinova et al., 2015; Manolov et al., 2015; Neshev & Manolov, 2014; Neshev et al., 2014; Goranovska et al., 2014).

In modern agriculture, weed control is mainly performed by the chemical method. A number

of authors study the selectivity and efficacy of different herbicides in crops (Glazunova et al., 2021; Marinov-Serafimov & Golubinova, 2016; Marinov-Serafimov & Golubinova, 2015; Mitkov, 2014; Mitkov et al., 2014; Mitkov et al., 2010; Tityanov et al., 2010; Tityanov et al., 2009; Mitkov et al., 2009; Atanasova, 2002).

The choice of a proper herbicide, optimal time, and application rate is one of the most important and responsible moments in wheat management (Petrova, 2017; Penchev & Petrova, 2015; Petrova & Sabev, 2014; Abbas et al., 2009a; Khalil et al., 2008; Sherawat & Ahmad, 2005).

For successful weed control in wheat, several herbicidal products are evaluated and applied. Mitkov et al. (2017a) study *Sekator OD* and *Biathlon 4 D* for control of dicotyledonous weeds. The herbicide products were applied in two terms – 1st – 2nd stem node (BBCH 30-32) and flag leaf (BBCH 37-39) of the wheat. The highest efficacy was recorded after the application of *Biathlon 4 D + Dash* at a rate of 0.14 kg ha⁻¹ + 1.0 l ha⁻¹ applied 1st – 2nd stem node of the crop. Chopra et al., (2008) found that carfentrazone at a rate of 20 g ha⁻¹ and metsulfuron at a rate of 4 g ha⁻¹ control the

broadleaf weeds 83.7 and 84.1% respectively. For control of the broadleaf weeds Abbas et al. (2009b) recommend the usage of Buktril Super EK - 835 ml ha⁻¹ and Starane-M - 875 ml ha⁻¹. WangCang et al. (2016), reported that the combinations of 29% fluroxypyr - 111.31 g ha⁻¹ + 5% carfentrazone-ethyl - 3.31 g ha⁻¹, florasulam - 7.50 g ha⁻¹ + carfentrazone-ethyl - 15.00 g ha⁻¹ had excellent efficacy against *Descurainia sophia*, *Capsella bursa-pastoris*, and *Galium aparine*. For the most efficient control of *Galium* sp. fluroxypyr should be applied.

High efficacy against *Galium aparine* after the combined treatment of carfentrazone + MCPP, trisulfuron + dicamba, and amidosulfuron + iodiosulfuron was recorded (Cirujeda et al., 2008).

For control of *Descurainia sophia* L. in winter wheat (*Triticum aestivum* L.) Wang et al., (2021) recommend the treatments with MCPA-Na + carfentrazone-ethyl and bipyrazone+fluroxypyr.

According to Zargar et al. (2021), it is better to achieve weed control in the autumn than in spring. Herbicide application at the early tillering stage of crops reduced the dry weight of broadleaf weeds by 60% to 90% and of monocot weeds by 55% to 85% (Meriem & Rafika, 2021).

It was found that tribenuron-methyl provided the greatest wild mustard suppression (75%) and also caused the highest reduction in wild mustard biomass (3.3 g), stem number (6), seed number (880), and germination percentage (33%) (Zargar et al., 2021).

Besides differentiated, the control of the mono- and dicotyledonous weeds in wheat could be performed simultaneously. For *Apera spica-venti*, *Echinochloa crus-galli* and some dicotyledonous weeds Szemendera et al., (2008) found that Pledge 50 WP (flumioxazine) can be applied. If there is mixed weed infestation with *Apera spica-venti*, *Lolium* sp., *Avena fatua*, *Myosotis arvensis*, *Capsella bursa-pastoris*, *Thlaspi arvense*, etc.

Krato and Raffel (2018) observed that treatment with Avoxa (pinoxadene+pyroxulam + cloquintocet-mexyl) at a rate of 1.8 l ha⁻¹ may be performed.

The study aims to establish herbicidal weed control in winter wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

During 2019-2020 and 2020-2021 a field trial with winter wheat variety “Enola” was performed. The experiment was situated on the experimental field of the department of “Agriculture and herbology” at the Agricultural University of Plovdiv, Bulgaria. The trial was conducted by the randomized block design in 3 replications. The size of the harvesting plot was 20 m². Variants of the trial were: 1. Untreated control; 2. Quelex (104.232 g/kg halauxifen-methyl + 100 g/kg florasulam) – 37.5 g ha⁻¹ + Trend 90 (90 % isodecyl alcohol ethoxylate + 10 % water) – 0.1%; 3. Quelex – 50 g ha⁻¹ + Trend 90 – 0.1%; 4. Quelex – 37.5 g ha⁻¹ + Aminopielik 600 SL (600 g/l 2.4 D amine salt) – 0.4 l ha⁻¹; 5. Quelex + Aminopielik 600 SL – 50 g ha⁻¹ + 0.4 l ha⁻¹; 6. Quelex – 37.5 g ha⁻¹ + Mustang 306.25 SC (6.25 g/l florasulam + 300 g/l 2.4 D ester) – 0.3 l ha⁻¹; 7. Derby Super One (150 g/kg florasulam + 300 g/kg aminopyralid) – 33 g ha⁻¹ + Trend 90 – 0.1%; 8. Mustang 306.25 SC – 0.6 l ha⁻¹; 9. Sekator OD (25 g/l iodiosulfuron-methyl-sodium + 100 g/l amidosulfuron sodium + 250 g/l mefenpyr-diethyl) – 1.25 l ha⁻¹; 10. Sekator OD - 1.50 l ha⁻¹ and 11. Biathlon 4D (54 g/kg florasulam + 714 g/kg tritosulfuron) – 55 g ha⁻¹ + Dash (0.5 l ha⁻¹).

As the studied herbicides are entire with broadleaf weed spectrum of control, for removing the grass weeds pressure, the application of Axial 050 EC (50 g/l pinoxaden) at a rate of 900 ml ha⁻¹ as background treatment to the whole experimental area was applied. The spraying was done in the tillering stage of the crop in spring.

The preceding crop of winter wheat during both experimental years was sunflower (*Helianthus annuus* L.). After the preceding crop harvesting twice disking and twice harrowing on 10 cm of depth was performed.

To the whole experimental area before sowing of the winter wheat, fertilization with 300 kg ha⁻¹ with NPK (15:15:15) 300 kg ha⁻¹ NH₄NO₃ as spring dressing.

Artificial weed infestation with previously collected weed seeds by spreading to the whole area of the trial was performed. The infestation was done with *Anthemis arvensis* L., *Papaver rhoeas* L., *Galium aparine* L., *Sinapis arvensis*

L., *Lamium purpureum* L., *Veronica hederifolia* L., *Consolida orientalis* (J.Gay) Sch., *Lamium purpureum* L., *Fumaria officinalis* L., and *Vicia hirsuta* L.

The application of the herbicide products was done in tillering stage of the crop (BBCH 21-29) with spraying solution 250 l ha⁻¹.

The efficacy of the herbicides was evaluated on the 14th, 28th, and the 56th day after treatments by the 10-score scale of EWRS (Zhelyazkov et al. 2017).

The selectivity of the herbicides was examined on the 7th, 14th, 28th, and 56th day after application by the 9-score scale of EWRS (Zhelyazkov et al. 2017).

The following parameters of the winter wheat were determined: Height of the plants at the end of the vegetation, length of the central ear, number of grains per ear, the mass of the grain per ear, 1000 grain weight, and grain yield.

The reported biometric indicators were processed with the software package SPSS 19 - module two-factor analysis of variance for Windows 10. The difference between the evaluated treatments was statistically analyzed by ONE WAY ANOVA by using Duncan's multiple range test. Statistical differences were considered proved at p<0.05.

RESULTS AND DISCUSSIONS

On the experimental field, only annual broadleaf weeds during both vegetation seasons of the winter wheat were observed. The weeds were presenters of three biological weed groups. The highest population was from the

group of the winter-spring weeds - *Anthemis arvensis* L., *Papaver rhoeas* L., *Consolida orientalis* (J.Gay) Sch. and *Vicia hirsuta* L., followed by the group of the early-spring weeds - *Galium aparine* L., *Sinapis arvensis* L., *Lamium purpureum* L., and two presenters of the ephemerals - *Veronica hederifolia* L. and *Fumaria officinalis* L.

One of the sensitive weeds to the evaluated herbicides and rates was *A. arvensis*.

The average results show that on the 14th day after application the efficacy against the weed varied from 57.5 to 78.2%.

On the 28th day after treatment, all studied variants showed very good efficacy. It was reported that after application of Biathlon 4D + Dash (55 g ha⁻¹ + 0.5 l ha⁻¹) and Quelex + Mustang 306,25 SC (37.5 g ha⁻¹ + 0.3 l ha⁻¹) during the second reporting date the efficiency against *A. arvensis* was 99.4%.

On the third reporting date, on average for the two years, 100% efficacy for all herbicide-treated variants except Quelex + Trend 90 (37.5 g ha⁻¹ + 0.1%) was reported (Table 1). Effective control against *A. arvensis* was also found from Kieloch (2005) after the application of Herbaflex 585 SC (isoproturon 500 g/l+beclufbutamid 85 g/l).

Against the weed *P. rhoeas* the highest control on the 14th day after application of Quelex + Mustang 306,25 SC (37.5 g ha⁻¹ + 0.3 l ha⁻¹) was recorded - 81.3%. Similar efficacy was found for the treatments with Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) - 78.2% and Mustang 306,25 SC (0.6 l ha⁻¹) - 75.7%.

Table 1. Efficacy of the studied herbicides against *Anthemis arvensis* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	60.0	95.0	98.8	55.0	90.0	97.5	57.5	92.5	98.2
3.	76.3	97.5	100	70.0	92.5	100	73.2	95.0	100
4.	70.0	98.8	100	65.0	95.0	100	67.5	96.9	100
5.	78.8	98.8	100	72.5	95.0	100	75.7	96.9	100
6.	80.0	100	100	75.0	98.8	100	77.5	99.4	100
7.	75.0	97.5	100	70.0	92.5	100	72.5	95.0	100
8.	78.8	97.5	100	72.5	92.5	100	75.7	95.0	100
9.	78.8	98.8	100	72.5	95.0	100	75.7	96.9	100
10.	81.3	97.5	100	75.0	92.5	100	78.2	95.0	100
11.	78.8	100	100	72.5	98.8	100	75.7	99.4	100

On the 28th day, on average for the period, the same tendency was observed. In treatment 6 the efficiency against *P. rhoeas* reached 100%, and for treatments 5 and 8 - 96.9% and - 96.3% respectively.

At the last reporting date, 100% control against *P. rhoeas* in variants 3, 4, 5, 6, 8, and 11 was found. The lowest efficiency was for Sekator OD at a rate of 1.25 l ha⁻¹ - 79.9% (Table 2).

Idziak et al., 2012 found that the mixture of pinoxaden with florasulam, applied alone or with different herbicides (fluroxypyr, tribenuron-methyl, dicamba with triasulfuron, 2,4-dichlorophenoxy acetic acid with dicamba) provides effective control of the weed *Papaver rhoeas*, *Galium aparine*, *Myosotis arvensis*, *Capsella bursa-pastoris*, and *Stellaria media*, *Matricaria inodora*.

Table 2. Efficacy of the studied herbicides against *Papaver rhoeas* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	57.5	90.0	97.5	52.0	85.0	92.5	54.8	87.5	95.0
3.	73.8	96.3	100	70.0	92.5	100	71.9	94.4	100
4.	71.3	95.0	100	68.5	90.0	100	69.9	92.5	100
5.	81.3	98.8	100	75.0	95.0	100	78.2	96.9	100
6.	83.8	100	100	78.8	100	100	81.3	100	100
7.	68.8	91.3	97.5	62.5	86.3	92.5	65.7	88.8	95.0
8.	78.8	97.5	100	72.5	95.0	100	75.7	96.3	100
9.	47.5	78.8	81.3	40.0	75.0	78.5	43.8	76.9	79.9
10.	51.3	85.0	88.8	45.0	80.0	85.0	48.2	82.5	86.9
11.	58.8	92.5	100	52.5	87.5	100	55.7	90.0	100

For *Galium aparine* L. control the highest results for the treatments with Quelex + Trend 90 (50 g ha⁻¹ + 0.1%), Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) and Quelex + Mustang 306,25 SK (37.5 g ha⁻¹ + 0.3 l ha⁻¹) were achieved.

On average for the period on the 14th day, the

efficiency varies from 61.2 to 80.7%, the highest being in variants 5 and 6.

On day 28, the efficacy against the weed increased and ranged from 85% with Sekator OD at a rate of 1.25 l ha⁻¹ to 96.9% with Quelex + Aminopielik 600 SL at a rate of 50 g ha⁻¹ + 0.4 l ha⁻¹.

Table 3. Efficacy of the studied herbicides against *Galium aparine* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	67.5	90.0	96.3	62.5	85.0	91.0	65.0	87.5	93.6
3.	77.5	97.5	100	75.0	92.5	100	76.3	95.0	100
4.	75.0	92.5	98.8	70.0	87.5	95.0	72.5	90.0	96.9
5.	81.3	98.8	100	80.0	95.0	100	80.7	96.9	100
6.	81.3	97.5	100	80.0	92.5	100	80.7	95.0	100
7.	65.0	88.8	95.0	60.0	85.0	90.0	62.5	86.9	92.5
8.	71.3	92.5	96.3	65.0	87.5	91.0	68.2	90.0	93.7
9.	66.3	87.5	93.8	62.5	82.5	90.0	64.4	85.0	91.9
10.	66.3	90.0	97.5	62.5	85.0	92.5	64.4	87.5	95.0
11.	63.8	90.0	96.3	58.5	85.0	91.0	61.2	87.5	93.7

On the 56th day, the average efficiency of all variants is from very good to excellent. The efficacy against *G. aparine* was 100% for the treatments of Quelex + Trend 90 (50 g ha⁻¹ + 0.1%), Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) and Quelex + Mustang 306,25 SK (37.5 g ha⁻¹ + 0.3 l ha⁻¹). In the other variants of

the third reporting date, the control against the glue varied from 91.9 to 96.9% (Table 3). Successful control with the *G. aparine* was also established after the application of Aminopielik Gold 530 EW (450 g/l 2,4-D + 80 g/l fluroxypyr) (Skrzypczak and Pudętko, 2004).

Average for the period on the 14th day after treatments against the weed *S. arvensis* the efficacy of Quelex + Trend 90 (50 g ha⁻¹ + 0.1%) and Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) was 82.5%. The efficacy of the other treatments varied from 64.4 to 75.3%. On the 28th day, the highest efficacy was observed for Quelex + Trend 90 (50 g ha⁻¹ + 0.1%) – 96.9%. It is worth noting that the use of Quelex + Aminopielik 600 SL at rates of 37.5 g ha⁻¹ + 0.4 l ha⁻¹ and 50 g ha⁻¹ + 0.4 l ha⁻¹

and Mustang 306.25 SK at a rate of 0.6 l ha⁻¹ provided 93.8% control of *S. arvensis*. On the 56th day after application, the efficacy in all variants was approximately excellent. Only in the Quelex + Trend 90 variant at the rate of 37.5 g ha⁻¹ + 0.1% the efficacy against *S. arvensis* was 95.7%. In the other variants, the control varied from 97.5 to 100% (Table 4) High efficacy of Mustang 306.25 SK, Secator OD, and Derby super WG against *S. arvensis* was also found by Petrova, 2017.

Table 4. Efficacy of the studied herbicides against *Sinapis arvensis* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	75.0	92.5	96.3	70.0	87.0	95.0	72.5	89.8	95.7
3.	85.0	98.8	98.8	80.0	95.0	100	82.5	96.9	99.4
4.	77.5	95.0	97.5	73.0	92.5	97.5	75.3	93.8	97.5
5.	85.0	95.0	98.8	80.0	92.5	100	82.5	93.8	99.4
6.	78.8	93.8	100	74.0	90.0	100	76.4	91.9	100
7.	75.0	91.3	98.8	70.0	85.0	100	72.5	88.2	99.4
8.	70.0	95.0	100	68.5	92.5	100	69.3	93.8	100
9.	66.3	92.5	100	62.5	87.0	100	64.4	89.8	100
10.	76.3	91.3	100	72.5	85.0	100	74.4	88.2	100
11.	75.0	93.8	100	70.0	90.0	100	72.5	91.9	100

The biological efficacy of the studied herbicidal products against *V. hederifolia* was among the lowest in comparison to those of the other weeds in the research. Average for the period the highest efficacy against the weed on the 14th day after treatment with Quelex + Mustang 306.25 SK (37.5 g ha⁻¹ + 0.3 l ha⁻¹) – 76.3%, followed by Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) - 75.1% was found. The efficacy of Derby Super One + Trend 90 (33 g ha⁻¹ + 0.1%) was barely 31.9%.

On the 28th day the highest efficacy was found to be for Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) and Quelex + Mustang 306,25 SK (37.5 g/da + 0.3 l ha⁻¹) - 91.9%. On average for the period on the 56th day against *V. hederifolia* was 100% for the Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) treatment. The lowest efficacy was reported for treatment 7-46.9% (Table 5).

Table 5. Efficacy of the studied herbicides against *Veronica hederifolia* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	36.3	45.0	50.0	32.5	40.0	47.5	34.4	42.5	48.8
3.	63.8	71.3	73.8	60.0	68.8	70.0	61.9	70.1	71.9
4.	62.5	88.8	95.0	58.5	85.0	92.5	60.5	86.9	93.8
5.	76.3	93.8	100	73.8	90.0	100	75.1	91.9	100
6.	77.5	93.8	98.8	75.0	90.0	95.0	76.3	91.9	96.9
7.	33.8	42.5	48.8	30.0	37.5	45.0	31.9	40.0	46.9
8.	66.3	88.8	95.0	62.5	85.0	92.5	64.4	86.9	93.8
9.	42.5	51.3	53.8	40.0	48.8	52.5	41.3	50.1	53.2
10.	47.5	61.3	63.8	42.5	57.5	60.0	45.0	59.4	61.9
11.	38.8	50.0	52.5	35.0	45.0	50.0	36.9	47.5	51.3

According to Kierzek and Adamczewski (2005) the mixture of 2.4 D + dicamba applied alone and with adjuvants (RA 2003, Olbras Super 90 EC, Olbras 88 EC or Atpolan 80 EC at 1.0 l ha⁻¹) was very effective to approximately all existing weeds in their study. The adjuvants have increased the efficacy of 22.4 D + dicamba, especially against *Veronica hederifolia*, *Papaver rhoeas*, and *Galium aparine*.

Compared to the *V. hederifolia* the weed *C. orientalis* was more sensitive to the studied herbicides. During the first reporting date, the average efficiency for the period varied from 60 to 81.9%.

On the 28th day, the efficacy increased, and for the treatment, with Quelex + Mustang 306.25 SK at rates of 37.5 g ha⁻¹ + 0.3 l ha⁻¹ reached 100%. For the other variants, the efficiency varies from 88.2% to 96.9%.

On the 56th day after treatment, in 2021, 100% control was reported for all herbicide variants, except for variants 7 and 11, where the efficacy was 98.8%.

On average for the period during the third reporting date the control with the *C. orientalis* in variants 3, 4, 5, 6, 8 was 100%, in variants 2, 9, 10 is 99.4%, and in variants 7 and 11-98.2% (Table 6).

Table 6. Efficacy of the studied herbicides against *Consolida orientalis* (J. Gay) Sch., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	62.5	92.5	98.8	57.5	88.8	100	60.0	90.7	99.4
3.	80.0	95.0	100	75.0	90.0	100	77.5	92.5	100
4.	78.8	93.8	100	72.5	90.0	100	75.7	91.9	100
5.	82.5	98.8	100	78.5	95.0	100	80.5	96.9	100
6.	83.8	100	100	80.0	100	100	81.9	100	100
7.	63.8	91.3	97.5	58.8	85.0	98.8	61.3	88.2	98.2
8.	66.3	97.5	100	60.0	94.0	100	63.2	95.8	100
9.	68.8	91.3	98.8	62.5	85.0	100	65.7	88.2	99.4
10.	71.3	92.5	98.8	67.5	88.8	100	69.4	90.7	99.4
11.	66.3	92.5	97.5	60.0	88.8	98.8	63.2	90.7	98.2

On the 14th day after the herbicidal spraying spraying the weed *L. purpureum* was most successfully controlled by Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) – 89.4%, followed by Quelex + Trend 90 (50 g ha⁻¹ + 0.1%), Quelex + Aminopielik 600 SL

(37.5 g ha⁻¹ + 0.4 l ha⁻¹) and Sekator OD 1.25 l da⁻¹) – 80.7%. On the second reporting date at treatments 3, 4, 5, 6, and 10 the efficacy was 100%. It was observed that on the 56th day the weed's control was excellent for all treatments (Table 7).

Table 7. Efficacy of the studied herbicides against *Lamium purpureum* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	76.3	96.3	100	70.0	95.0	100	73.2	95.7	100
3.	82.5	100	100	78.8	100	100	80.7	100	100
4.	82.5	100	100	78.8	100	100	80.7	100	100
5.	91.3	100	100	87.5	100	100	89.4	100	100
6.	80.0	100	100	75.0	100	100	77.5	100	100
7.	78.8	96.3	100	75.0	95.0	100	76.9	95.7	100
8.	66.3	95.0	100	60.0	92.5	100	63.2	93.8	100
9.	82.5	98.8	100	78.8	100	100	80.7	99.4	100
10.	81.3	100	100	77.5	100	100	79.4	100	100
11.	80.0	98.8	100	75.0	100	100	77.5	99.4	100

In the control against *F. officinalis* on the first reporting date, the efficacy of Quelex + Mustang 306.25 SK at rates of 37.5 g ha⁻¹ + 0.3

l ha⁻¹ was the highest - 82.5%, followed by Quelex + Aminopielik 600 SL at rates of 50 g ha⁻¹ + 0.4 l ha⁻¹ - 75.7%.

On the 28th day, the highest efficacy of the weed for treatment 6 was reported. On average for the period on the 56th day 100% efficacy after the use of Quelex + Mustang 306,25 SK (37.5 g ha⁻¹ + 0.3 l ha⁻¹), Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹), Quelex + Aminopielik 600 SL (37.5 g ha⁻¹ + 0.4 l ha⁻¹),

Quelex + Trend 90 50 g ha⁻¹ + 0.1%) was reported. Limited control of *Fumaria officinalis* L. was found for Sekator OD (1.25 l ha⁻¹), Mustang 306.25 SK (0.6 l ha⁻¹), Biathlon 4D + Dash (55 g ha⁻¹ + 0.5 l ha⁻¹) and Sekator OD (1.50 l ha⁻¹) (Table 8).

Table 8. Efficacy of the studied herbicides against *Fumaria officinalis* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	62.5	92.5	96.3	60.0	90.0	95.0	61.3	91.3	95.7
3.	75.0	97.5	100	70.0	92.5	100	72.5	95.0	100
4.	67.5	97.5	100	62.5	92.5	100	65.0	95.0	100
5.	78.8	95.0	100	72.5	90.0	100	75.7	92.5	100
6.	85.0	100	100	80.0	97.5	100	82.5	98.8	100
7.	55.0	93.8	97.5	50.0	90.0	98.8	52.5	91.9	98.2
8.	41.3	57.5	57.5	38.5	50.0	52.5	39.9	53.8	55.0
9.	42.5	50.0	55.0	40.0	45.0	50.0	41.3	47.5	52.5
10.	45.0	55.0	61.3	42.5	50.0	57.5	43.8	52.5	59.4
11.	48.8	60.0	60.0	45.0	55.0	55.0	46.9	57.5	57.5

Regarding the weed species *V. hirsute* the herbicidal efficacy on the 14th day after treatments, the efficacy varied between 73.8% - 85.7%.

Excellent 100% efficacy was found for the variants with Quelex + Trend 90 (50 g ha⁻¹ + 0.1%), Quelex + Aminopielik 600 SL (37.5 g

ha⁻¹ + 0.4 l ha⁻¹ and 50 g ha⁻¹ + 0.4 l ha⁻¹), Quelex + Mustang 306.25 SK (37.5 g ha⁻¹ + 0.3 l ha⁻¹) on the 28th day.

On the last reporting date (56 days after treatments) the efficacy of all studied variants reached 100% (Table 9).

Table 9. Efficacy of the studied herbicides against *Vicia hirsuta* L., %

Variants	2020			2021			Average		
	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day	14 th day	28 th day	56 th day
1.	-	-	-	-	-	-	-	-	-
2.	77.5	96.3	100	70.0	90.0	100	73.8	93.2	100
3.	87.5	100	100	80.0	100	100	83.8	100	100
4.	86.3	100	100	80.0	100	100	83.2	100	100
5.	88.8	100	100	82.5	100	100	85.7	100	100
6.	83.8	100	100	78.5	100	100	81.2	100	100
7.	78.8	96.3	100	72.5	90.0	100	75.7	93.2	100
8.	78.8	97.5	100	72.5	92.5	100	75.7	95.0	100
9.	78.8	96.3	100	72.5	90.0	100	75.7	93.2	100
10.	78.8	96.3	100	72.5	90.0	100	75.7	93.2	100
11.	80.0	98.8	100	75.0	95.0	100	77.5	96.9	100

All studied herbicidal products and rates are selective for the winter wheat variety Enola.

Regarding the indicator plant height, it was found that of all the studied variants, the plants in the untreated control are the shortest.

This difference is statistically proven at a significance level of 5%.

The results show that if there is weed pressure it leads to concurrence with the cultivated plant that leads to growth and development decrease.

On average for the two years of study treatments 2, 3, 4, 5, 6, 7, 8, 10, and 11 did not differ significantly from in plant height ranging from 84.7 cm to 89 cm.

With lower plant height were the treatments with Sekator OD (1.25 l ha⁻¹) and Biathlon 4D + Dash (55 g ha⁻¹ + 0.5 l ha⁻¹) - 80.3 and 81.7 cm respectively (Table 10).

Table 10. Height of the plants, length of the central ear, and number of grains per ear of wheat, Enola variety

Variants	2020			2021			Average		
	Height of the plants , cm	length of the dental ear, cm	number of grains per ear	Height of the plants , cm	length of the dental ear, cm	number of grains per ear	Height of the plants , cm	length of the dental ear, cm	number of grains per ear
1.	72.5 f	6.1 f	25.1 f	69.1 f	5.7 d	21.4 e	70.8 d	5.9 f	23.3 e
2.	87.3 bc	8.6 bcd	42.5 bc	83.2 bc	8.0 b	41.9 bc	85.3 abc	8.3 bcd	42.2 bc
3.	88.4 abc	9.5 abc	46.0 b	84.2 abc	8.4 ab	44.1 b	86.3 abc	9.0 ab	45.1 b
4.	89.9 abc	9.6 ab	48.2 b	85.6 abc	8.5 ab	45.7 b	87.8 ab	9.1 a	47.0 b
5.	90.5 ab	9.9 a	57.0 a	86.2 ab	9.0 a	51.4 a	88.4 a	9.5 a	54.2 a
6.	91.1 a	10.0 a	57.4 a	86.8 a	9.1 a	53.3 a	89.0 a	9.6 a	55.4 a
7.	88.0 abc	8.6 bcd	42.8 bc	83.2 bc	8.0 b	42.1 bc	85.5 abc	8.3 bcd	42.5 bc
8.	87.6 bc	9.3 abc	44.0 bc	83.4 abc	8.4 ab	43.1 bc	85.6 abc	8.9 ab	43.6 bc
9.	82.2 e	7.5 e	34.3 d	78.3 e	7.0 c	32.8 d	80.3 c	7.3 e	33.6 d
10.	86.7 cd	8.6 cd	41.3 bc	82.6 cd	7.8 b	40.3 bc	84.7 abc	8.2 cd	40.8 bc
11.	83.6 de	8.1 de	36.1 d	79.7 de	7.8 b	35.8 d	81.7 bc	8.0 d	36.0 d

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

In the indicator of the length of the central ear, a statistical difference between the untreated control and the herbicide-treater variants was recorded. According to the degree of mathematical proof, six separate groups are distinguished – "a", "b", "c", "d", "e" and "f". The lowest results were found for the untreated control – 5.9 cm, belonging to a group „f". The most distant from the group of untreated control – "f". and with the highest value of the studied indicator are the treatments with Quelex + Mustang 306,25 SK ($37.5 \text{ g ha}^{-1} + 0.3 \text{ l ha}^{-1}$), Quelex + Aminopielik 600 SL ($50 \text{ g ha}^{-1} + 0.4 \text{ l ha}^{-1}$), Quelex + Aminopielik 600 SL ($37.5 \text{ g ha}^{-1} + 0.4 \text{ l ha}^{-1}$), Quelex + Trend 90 ($50 \text{ g ha}^{-1} + 0.1\%$) and Mustang 306,25 SK (0.6 l ha^{-1}), belonging to a group „a". The was no statistically proved difference also between the treatments with Derby Super One + Trend 90 ($33 \text{ g ha}^{-1} + 0.1\%$), Quelex + Trend 90 ($37.5 \text{ g ha}^{-1} + 0.1\%$), Sekator OD (1.50 l ha^{-1}) and Biathlon 4D + Dash ($55 \text{ g ha}^{-1} + 0.5 \text{ l ha}^{-1}$) (Table 10).

The results related to the number of grains from the central ear showed that there are statistically proven differences between the untreated control and the other studied variants in favor of the herbicide-treated ones. The highest grain number was found for the treatments with Quelex + Mustang 306,25 SK ($37.5 \text{ g ha}^{-1} + 0.3 \text{ l ha}^{-1}$) Quelex + Aminopielik

600 SL ($50 \text{ g ha}^{-1} + 0.4 \text{ l ha}^{-1}$) - 55.4 and 54.2 respectively. Lower grain number was recorded for treatments 9 and 11 - 33.6 and 36.0 respectively. The lowest grain number for the untreated control was recorded - 23.3 (Table 10).

Average for the period the central ear grain mass was the lowest for the untreated control – 0.66 g. The obtained result was statistically proved with the other treatments. The highest mass of the grains from the central ear was found to be for treatments 6, 5, 4, and 3 – 2.14, 2.02, 1.91, and 1.75 g respectively. There is no mathematically proven difference between these four options (Table 11).

The indicator 1000 grain weight gives an idea of the size and obesity of the seeds. The obtained results showed that there is a statistically proven difference between the untreated control and the herbicide-treated variants. The untreated control had the lowest value of the studied indicator - 26.32 g. The highest results for treatments 6, 5, 4, 3, 8, 7, and 2 were recorded. Lower values of this indicator, but with a proven higher difference from the control were treatments 10, 11, and 9 - 34.78, 32.38, and 31.70 g respectively (Table 11). Marczevska-Kolasa and Kieloch (2009) also found that the use of herbicides significantly increases the 1000 grain weight than in the untreated control.

Table 11. Mass of the grain per ear and 1000 grain weight of wheat, Enola variety

Variants	2020		2021		Average	
	mass of the grain per ear, g	1000 grain weight, g	mass of the grain per ear, g	1000 grain weight, g	mass of the grain per ear, g	1000 grain weight, g
1.	0.73 g	27.04 f	0.59 g	25.60 f	0.66 f	26.32 e
2.	1.53 def	37.60 cd	1.27 def	34.81 bc	1.40 de	36.21 abc
3.	1.90 abcd	39.00 bc	1.59 abcd	35.93 bc	1.75 abcd	37.47 ab
4.	2.06 abc	40.12 ab	1.75 abc	36.24 bc	1.91 abc	38.18 ab
5.	2.18 ab	40.58 ab	1.85 ab	38.10 ab	2.02 ab	39.34 a
6.	2.30 a	41.19 a	1.97 a	39.85 a	2.14 a	40.52 a
7.	1.70 cde	38.00 cd	1.43 cde	35.25 bc	1.57 cde	36.63 abc
8.	1.83 bcde	38.12 bc	1.50 bcde	35.5 bc	1.67 bcd	36.81 ab
9.	1.27 f	33.5 e	1.01 f	29.89 e	1.14 e	31.70 d
10.	1.45 ef	36.20 cd	1.16 ef	33.35 cd	1.31 de	34.78 bcd
11.	1.30 f	34.00 e	1.02 f	30.75 de	1.16 e	32.38 cd

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

Data on winter wheat yield confirm that there is a positive correlation between the effect of herbicides on weeds and the yield obtained from the crop. As a result of the high weed infestation of the experimental field, a low average yield from the untreated control was reported - 2.75 t ha⁻¹ (Table 12). According to the degree of mathematical proof, seven separate groups of treatments were distinguished - "a", "b", "c", "d", "e", "f" and "g". The application of Quelex + Mustang 306,25 SK (37.5 g ha⁻¹ + 0.3 l ha⁻¹) had the

highest grain yield - 5.34 t ha⁻¹. It is correct to mention that the application of Quelex + Aminopielik 600 SL (50 g ha⁻¹ + 0.4 l ha⁻¹) and Quelex + Aminopielik 600 SL (37.5 g ha⁻¹ + 0.4 l ha⁻¹) led to high grain yields as well - 5.21 and 5.12 t ha⁻¹ respectively. It was found that there was no proven difference between treatments 6, 5, and 4. These variants are from group "a" and are furthest from the group of untreated control "g", ie. with the highest yield (Table 12).

Table 12. Grain yield (t ha⁻¹) of wheat, variety Enola, treated with the tested herbicides

Variants	2020	2021	Average
1. Untreated contol	2.84 e	2.66 e	2.75 g
2. Quelex + Trend 90 (37.5 g ha ⁻¹ + 0.1%)	4.94 bc	4.72 bc	4.83 d
3. Quelex + Trend 90 (50 g ha ⁻¹ + 0.1%)	5.11 ab	4.92 ab	5.02 bcd
4. Quelex + Aminopielik 600 SL (37.5 g ha ⁻¹ + 0.4 l ha ⁻¹)	5.22 ab	5.01 ab	5.12 abc
5. Quelex + Aminopielik 600 SL (50 g ha ⁻¹ + 0.4 l ha ⁻¹)	5.31 ab	5.11 ab	5.21 ab
6. Quelex + Mustang 306,25 SC (37.5 g ha ⁻¹ + 0.3 l ha ⁻¹)	5.44 a	5.24 a	5.34 a
7. Derby super one + Trend 90 (33 g ha ⁻¹ + 0.1%)	4.98 bc	4.79 bc	4.89 cd
8. Mustang 306,25 SC (0.6 l ha ⁻¹)	5.03 b	4.83 ab	4.93 cd
9. Sekator OD (1.25 l ha ⁻¹)	4.23 d	3.99 d	4.11 f
10. Sekator OD (1.50 l ha ⁻¹)	4.62 cd	4.40 cd	4.51 e
11. Biathlon 4D + Dash (55 g ha ⁻¹ +0.5 l ha ⁻¹)	4.29 d	4.09 d	4.19 f

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

The lowest grain yield among the herbicide-treated variants for the treatments with Sekator OD at a rate of 1.25 l ha⁻¹ - 4.11 t ha⁻¹ and Biathlon 4D + Dash at a rate of 55 g ha⁻¹ + 0.5 l ha⁻¹ - 4.19 t ha⁻¹ was recorded. There is no proven difference between the two variants at p

< 0.05 . The obtained average yields in these variants can be explained by their lower herbicidal efficiency. However, in variants 9 and 11 the yield was proven to be higher than in the untreated control (Table 12). Increasing in wheat yields after the application of

herbicides have been found in other studies as well (Touahar et al., 2021; Yanev et al., 2021; Al-Khazali et al., 2020; Mitkov et al., 2018; Mitkov et al., 2017b).

CONCLUSIONS

The application of Quelex + Mustang 306,25 SK at rates of 37.5 g ha⁻¹ + 0.3 l ha⁻¹ had 100% efficacy *A. arvensis*, *P. rhoeas*, *G. aparine*, *S. arvensis*, *C. orientalis*, *L. purpureum*, *F. officinalis* and *V. hirsuta*.

The application of Quelex + Aminopielik 600 SL at rates of 50 g ha⁻¹ + 0.4 l ha⁻¹ showed 100% efficacy against *V. hederifolia* and the other weed species except *S. arvensis*, where the efficacy was 99.4%.

The most difficult-to-control weed in the study was *V. hederifolia*, followed by *F. officinalis*.

All studied herbicides show excellent selectivity to wheat, Enola variety.

The lowest results for the studied parameters as length of the central ear, number of grains per ear, mass of the grain per ear, 1000 grain weight and grain yield for the untreated control were reported. Statistically proven differences in favor of herbicide-treated variants have been identified.

After the application of Quelex + Mustang 306,25 SK at rates of 37.5 g ha⁻¹ + 0.3 l ha⁻¹ and Quelex + Aminopielik 600 SL in both evaluated rates (50 g ha⁻¹ + 0.4 l ha⁻¹ and 37.5 g ha⁻¹ + 0.4 l ha⁻¹) the highest values of all indicators, including grain yield were reported.

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